

APPLICATION FOR UNITED STATES PATENT

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Invention: **STRENGTHENED, LIGHT WEIGHT CONSTRUCTION BOARD**

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1 **STRENGTHENED, LIGHT WEIGHT CONSTRUCTION BOARD**

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4 **CROSS-REFERENCE TO RELATED APPLICATIONS**

5 The present application is a Continuation-in-Part Application of copending U.S. Patent
6 Application Serial No. 09/732,852, filed December 8, 2000, which application is a Continuation-
7 in-Part of U.S. Patent Application Serial No. 09/547,615, filed April 12, 2000, which application
8 is a Continuation-in-Part Application of copending U.S. Patent Application Serial No.
9 09/471,448, filed December 23, 1999, which application is a Continuation-in-Part Application of
10 copending U.S. Patent Application Serial No. 09/374,589, filed August 13, 1999, which
11 application is based upon and gains priority from U.S. Provisional Patent Application Serial No.
12 60/139,618, filed June 17, 1999 by the inventor herein and entitled "Improved Wallboard and
13 Method and Apparatus for Making the Same," and which application is also a Continuation-in-
14 Part Application of U.S. patent Application Serial No. 09/195,438, filed November 18, 1998 by
15 the inventor herein and entitled "Light Weight Fire and Moisture Resistant Wallboard."

16
17 **BACKGROUND OF THE INVENTION**

18 1. Field of the Invention.

19 This invention relates to new compositions that are useful in the manufacture of boards or
20 panels for use in construction applications. More particularly, this invention is directed to a
21 novel construction board or panel composition comprising a unique combination of synthetic
22 binders selected for their ability to establish a strengthened permanent bond in the final dry state,
23 in combination with gypsum and an expanded mineral such as Perlite. Utilizing such synthetic
24 binders provides an increased strength to the construction board core, enabling lighter-weight
25 Perlite to replace at least a portion of the heavier gypsum traditionally used in construction board

compositions. Moreover, the synthetic binders disclosed herein uniquely cross-link with the expanded mineral to form a much stronger bond between the constituent components of the construction board core material than that which has been available in previously known construction board products. In a preferred embodiment, the lightweight, strengthened construction board of the present invention also comprises a covering veneer of paper or fiber that is treated to further the fire retardant and moisture resistance of the product. Additionally, this invention relates to the unique manufacturing process to produce the construction board composition of the present invention in order to create a lightweight, strengthened, moisture resistant, and fire retardant panel to be used in construction applications.

2. Description of the Background

It is well known in the art to use planar panels or sheets formed from inorganic materials in the construction of walls, ceilings, floors, exterior sheathing, and similar construction elements, instead of applying wet plaster to such surfaces. Such panels may be applied to stud work comprising the walls, ceilings, floors, and exteriors of building structures in the form of wallboard, lath, sheathing, and the like, using nails, screws, or other fastening means. The use of calcium sulfate hemihydrate $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ in the manufacture of such construction panels has predominately been unchanged for over half a century. In general, these panels comprise essentially a core of set interlaced gypsum crystals disposed between fibrous, especially paper, liner sheets. After the gypsum slurry has set (i.e., reacted with the water from the aqueous slurry) and dried, the sheet is cut into standard board sizes.

Unfortunately, however, traditional gypsum construction boards can be quite heavy, causing quick fatigue to installers and delayed construction schedules, as well as large

1 transportation costs. Likewise, traditional construction boards often realize significant increases
2 in weight when particular construction applications require stronger construction panels, thus
3 making their use even more problematic.

4 Attempts to modify the composition of traditional gypsum panels in order to provide a
5 lighter weight construction panel have been made, but with little success or commercial viability.
6 For example, the addition of synthetic binders has very recently been attempted as disclosed in
7 U.S. Patent No. 5,879,825 to Burke et al.; however, the engineering and chemical research in
8 various combinations of complex chemical formulations and combinations thereof has been quite
9 limited. Additionally, Burke et al. fails to address the environmental concerns of noxious fumes
10 under fire engineering standard ASTM testing E119. Still further, cost considerations limit the
11 amount of acrylic polymer present in the Burke et al. composition to 1 to 2 percent, but the fact
12 that such acrylic polymer in Burke et al. employs a less than 10% solids ratio results in a
13 polymer having a minimal cross-linking performance with the other constituent elements.
14 Further, while the use of Perlite as an antidessicant to prevent the dehydration of gypsum crystals
15 formed during setting of the core composition is disclosed, no consideration is given to
16 introducing an expanded mineral, such as perlite, as a substitute for gypsum as one of the
17 structural foundations of the board core and as a strengthening agent when combined with
18 appropriate other constituent elements (as set forth below), nor the specific need for a synthetic
19 binder composition for establishing a complete cross-linking between the constituent elements of
20 the core in order to create a molecular change within the strengthening agent, which molecular
21 change is in turn required to completely bond a reduced amount of gypsum with the other
22 components of a construction board core.

1 It would therefore be highly advantageous to provide an improved, high strength,
2 lightweight construction panel product which reduces the need for gypsum in the panel
3 composition by means of displacing some of the normal amount of gypsum utilized with the
4 expanded mineral perlite, and which utilizes a synthetic binder composition that enables a
5 complete cross-linking of the constituent elements of the lighter construction panel core to form
6 a rigid structure with the structural integrity to withstand the structural requirements of
7 traditional construction panels. Such construction panels should meet industry requirements, and
8 likewise have a strength at least equal to previously known construction panels while reducing
9 the weight of the finished panel.

10
11 4. Summary of the Invention.

12 It is therefore an object of the instant invention to provide an improved, light weight,
13 strengthened gypsum construction board product that overcomes the disadvantages of the prior
14 art.

15 This and other objects are achieved through a composition consisting essentially of a
16 unique combination of synthetic binders selected for their ability to establish a permanent bond
17 in the dry state, combined with an expanded mineral (e.g., Perlite and crushed Perlite), organic
18 binding adhesives, drying agents, crystal growth enhancers, and gypsum with a sufficient
19 amount of water to form an aqueous slurry, all contained within a covering of treated moisture
20 and heat resistant paper material, which produces an improved lighter-weight, strengthened
21 gypsum construction board product. The technology of the present invention utilizes an
22 expanded mineral which fuses with the calcined gypsum mineral and physically becomes part of

1 the composite matrix due to the complex formulation of binders and gypsum attaching
2 themselves to the expanded mineral, instead of the expanded mineral only acting as a filler.

3 Perlite (expanded) can be graded by density in pounds per cubic foot, and classified by
4 product number or trade name for producer and user identification. The expanded product can
5 weigh as little as 2 pounds per cubic foot, but the most widely used bulk-density grade range is
6 from 7 to 15 pounds per cubic foot. The range of expanded Perlite utilized in the construction
7 board composite core of the present invention is 4 to 10 pounds per cubic foot, with 4 pounds per
8 cubic foot being preferred. It has been found that the more friable cryogenic and micro-sphere
9 grades in the 3 to 4 pound range are favorable, with 4 pounds being the most preferred, over the
10 heavier grades ranging from 5 to 10 pounds per cubic foot. Grades typical to this heavier range
11 include concrete, plaster, and cavity fill or masonry, which can also be utilized, but are not as
12 preferable as the lighter previously mentioned grades. The particle size ranges from 100 to 2,000
13 microns, and preferably from 200 to 1000 microns. Preferably, the expanded Perlite will have a
14 particle size ranging from no larger than 10 mesh sieve size and no smaller than 200 mesh sieve
15 size measured on standard screen scale. The particle size of the preferred expanded Perlite is
16 directly related to the strength of the construction board core in the aspect of fusion. Particles
17 that are too large tend to space gypsum crystal growth too far apart, and particles that are too
18 small do not allow enough area for the gypsum crystal to fuse onto. The particle size is not
19 directly related to the expansion method but can be controlled by means of properly sizing the
20 Perlite ore prior to expansion.

21 It was determined to be advantageous to use a polyvinyl acetate emulsion or vinyl acetate
22 homopolymer emulsion or water based non-V.O.C. acrylic or polyurethane emulsion for use in
23 the binder of the instant invention. While vinyl acetates of all types were found to be less costly

1 and performed well, vinyl acetate emulsions with 0.10% to 30% polyvinyl alcohol were further
2 preferred and found to provide unforeseen benefits over powdered polyvinyl acetates. First,
3 vinyl acetate emulsions containing polyvinyl alcohol are available at far less cost (approximately
4 one third) than powdered polyvinyl acetates. Further, vinyl acetate emulsions when properly
5 added and diluted for quick dispersion in the metered water or water solution feeds, prior to
6 entrance into the gypsum slurry mixer, dispersed and performed better than powdered polyvinyl
7 acetates, thus simplifying the manufacturing process and reducing costs caused by flawed
8 boards. Better results in terms of reactivity, dispersion, and ease of mixing occurred in test
9 samples when the vinyl acetate emulsions were strengthened and stabilized with polyvinyl
10 alcohol. It was discovered that the optimum molecular weight of the preferred polyvinyl alcohol
11 selected to strengthen and stabilize the vinyl acetate emulsion is a function of the type of gypsum
12 stucco prepared, and the length of time the final vinyl acetate emulsion needed to be stabilized.
13 In final prepared gypsum stuccos that had higher percentages of certain clays (i.e., above 1% of
14 clays commonly found in some gypsum deposits) naturally occurring in or with the gypsum ore,
15 lower molecular weight polyvinyl alcohols, preferably between 20 and 5000, exhibited better
16 results with less initial thickening of the wet gypsum slurry mix.

17 It has also been determined that the addition of small amounts of accelerators or
18 strengthening agents described below can be added to the final polyvinyl acetate emulsion to
19 increase strength and final composite set performance. To describe this macroscopically, the
20 binder is diluted in the processed water to disperse throughout the wet gypsum and perlite slurry
21 in the pin mixer. An accelerator or strengthening agent is added to the back side of the gypsum
22 slurry pin mixer, to begin to chemically increase the set of the binder once the formed
23 construction board is proceeding downstream to the rotary knife. Optimally, the initial set time of

1 the board is decreased such that the board can be cut in less time. Thus, the board line can be run
2 faster, producing more construction board in a shorter period of time. Potassium or other alkali
3 elements or compounds can be added at 0.001% to 3% of the total board wet weight at the last
4 stages to increase the rate of the set time of the binder and ultimately decrease the initial set of
5 the construction board. While Potassium Sulfate has been utilized to decrease the initial set time
6 of the green construction board prior to the knife, too high or too small amounts can actually
7 burn the gypsum crystals and create a “punky” or powdery final construction board that has lost
8 its strength. The binder (vinyl acetate emulsion, or water based non V.O.C. acrylic or
9 polyurethane emulsion) reacts with the accelerator (potassium sulfate) to retard or even eliminate
10 the burning of the gypsum crystals.

11 It has also been found that certain organic polymers, including aniline formaldehyde
12 resins, melamine formaldehyde resins, urea-formaldehyde resins, and urea-melamine
13 formaldehyde resins, may be combined with polyvinyl acetate or polyvinyl alcohol to provide an
14 alternative binder capable of fully crosslinking with the inorganic minerals of the composition in
15 order to form a strengthened composite core for a construction board.

16 Optionally, reinforcing fibers, fire retardants, water repellents, and other water proofing
17 materials may be part of the composition. More particularly, current gypsum construction board
18 core formulations, once dried, have common micro-cracks, form more brittle core composites,
19 and exhibit less tolerant processed board flexibility. Paper fibers, or other synthetic fibers, have
20 been utilized more in the past to hold the core composite together, yet have been insufficient to
21 stop board drying over time, and increase short and long term micro-cracking and ultimate core
22 breakdown or spot load failure. Thus, the development of the synthetic adhesive technology of

1 the instant invention has developed critical improvements to board flexibility, moisture retention,
2 and long term, sustained and improved strength.

3 Actual plant manufacturing test runs of the construction board compositions described
4 herein were conducted for several hours each, and using a variety of gypsum ore and gypsum
5 stucco preparation methods. The test runs showed improved ASTM test results at each run. The
6 process of introducing and adding sufficient amounts of the synthetic binder into the final
7 gypsum stucco was successfully completed during each test run. However, improved results
8 occurred when the binder was diluted in the metered water or other prepared water solutions, for
9 direct feed prior to the gypsum slurry mixer. Higher ASTM lab test results occurred when
10 utilizing the optimum design combinations and percentages set forth in the examples below of
11 vinyl acetate and water based non-V.O.C. acrylic or polyurethane emulsions, with each particular
12 type of gypsum stucco supplied during the test runs. Thus, by optimizing the final polyvinyl
13 acetate homopolymer or water based non-V.O.C. acrylic or urethane polymer emulsion,
14 optimum test results were achieved in both the test lab and in actual manufacturing test samples.

15 Thus, the test run results showed that the construction board composition of the instant
16 invention provides a number of benefits over previously known construction board products.

17 First, the present invention allows for a construction board composition that is
18 significantly lighter in weight (up to fifty percent lighter) than current traditional heavy gypsum
19 construction board formulations. This reduced weight also results in transporting lighter loads,
20 in turn reducing transportation costs. Further, job site labor costs are reduced by enabling the
21 workers to handle lightened loads, such that the installation process is made easier and less
22 costly. Similarly, the potential for heavy board related injury accidents to the tradesmen that
23 install the construction board product is reduced.

1 Further, the construction board composition of the instant invention exhibits equal or
2 greater strength than current heavy gypsum construction board, with improvements in moisture
3 resistance and flame resistance that exceeds current industry standards. This lightweight and
4 strength factor equates to decreased structural support load bearing and lessens the total support
5 strength required in any project, in turn further reducing overall construction costs.

6 Yet another benefit of the strengthened construction board of the instant invention is the
7 reduction in the amount of board breakage (and in the amount of airborne particulates associated
8 with such breakage) and losses due to manual or machine transport to the installation site, due to
9 the fact that the composition of the instant invention provides the construction board with greater
10 flexibility than has been known in previous construction board compositions.

11 Yet another benefit of the composition utilized in the instant invention is the "clean-snap"
12 characteristics exhibited by a finished construction board when the board is cut with a utility
13 knife. The attempted addition of synthetic binders in the past to construction board compositions
14 have reduced the ability to cut the finished construction board sheet during installation with a
15 utility knife. However, the composition of the instant invention was developed after extensive
16 testing and analysis of numerous chemical combinations, with extensive chemical technical
17 research and testing to realize a brittle cross-linking complex polymer that combines and fuses
18 with the mineral and expanded mineral, that is easily cut and snapped with a utility knife as
19 applied in standard construction industry use.

20 The specific binders described below as a constituent element of the compositions used
21 herein also provide specific benefits related to the characteristics and manufacturing economics
22 of the construction board of the instant invention. Water based vinyl acetate, non-V.O.C acrylic
23 and non-V.O.C. polyurethane emulsions tested were selected and preferred over other

1 petrochemical-based emulsions or liquid plastics for several specific reasons. First, the most
2 crucial practical factors in selecting the preferred type of adhesive are performance of the
3 adhesive in binding the construction board core, and cost relative to that performance, and the
4 compatibility of the particular emulsion with the other specific constituents of the sheathing core.

5 Such cost factors include both the cost of the base components, such as vinyl acetate
6 monomer (VAM) (which today is preferably produced from ethylene) that make up the adhesive,
7 and the cost to make the final product. It was found that vinyl acetates provide the lowest cost,
8 while water based non-V.O.C. acrylic and polyurethane polymers provided non-toxic and
9 environmentally safe high performance at a slightly higher but not unreasonable cost, while all
10 three maintained assurance of high adherence and coherence capabilities to attach to the minerals
11 in the construction board core, namely, gypsum and/or perlite. Also, a deliberate effort was
12 made to determine and utilize a low cost, final stage, brittle-type plastic in emulsion or liquid
13 initial state, that when hardened would have the ease of a clean snap when cut with a utility
14 knife. It was discovered that the vinyl acetate adhesive family and the non-V.O.C. acrylic and
15 polyurethane families performed superior to sodium silicates in meeting these requirements, even
16 though sodium silicates were lower in overall cost.

17 Furthermore, it was found that the blending of organic polymers, including aniline
18 formaldehyde resins, melamine formaldehyde resins, urea-formaldehyde resins, and urea-
19 melamine formaldehyde resins, may provide superior adhesion and cohesion properties while
20 enabling an overall lower cost yet fully crosslinking binder. Such blended polymers provide
21 superior crosslinking between the organic and inorganic materials used in the manufacture of
22 construction board.

1 Regarding the compatibility of the emulsion with the other constituents of the
2 construction board core, test results proved that water solubility of the adhesives and ease of
3 dispersion into the final core composite was crucial to fabricating the construction board without
4 paper blows and peels due to insufficient or improper re-hydration of the calcined gypsum. In all
5 of the tests performed, results showed favorably toward the latex water based emulsions for the
6 best compatibility and ease of dispersion when added into the system with no adverse affect on
7 hydration. The preferred polymer systems of the instant invention provided for complete
8 hydration of the gypsum as well as improving upon the paper to core bond in every instance of
9 its use. The latex water based emulsions also worked best at the drier end of the line (in the kiln)
10 as they didn't react poorly or inhibit evaporation due to filming and/or agglomeration and
11 blistering due to improper dispersion into the slurry.

12 Also, it was discovered that board flexibility during actual board installation, or during
13 the manufacture of the board as it travels over rollers and curved rises in and out of the drying
14 kilns, was improved through the use of more plastic adhesives (such as vinyl acetate and non-
15 V.O.C. acrylic and polyurethanes) as the binder.

16 Yet another benefit of the binder formulations utilized in the construction board of the
17 instant invention lies in their ability to easily cross link with the other constituent elements of the
18 formulations provided below. Vinyl acetates were found to react well and cross-link in the
19 presence of boron with starches to create a final tacky binder, at the proper percentages set forth
20 below, that forms a brittle plastic excellent for binding the core of the construction board product
21 in such a way as to maintain superior strength characteristics while reducing the overall weight
22 of the board. Likewise, as mentioned briefly above and as set forth in greater detail below,
23 blended polymers comprising organic polymers (aniline formaldehyde resins, melamine

1 formaldehyde resins, urea-formaldehyde resins, and urea-melamine formaldehyde resins) and
2 inorganic polymers (polyvinyl acetate and polyvinyl alcohol) were found to completely crosslink
3 with the inorganic minerals of the composition to form a strengthened composite core for a
4 construction board.

5 The improved, strengthened core material of the instant invention also provides increased
6 compression, shear, and tension loading test results in comparison with the conventional non-
7 reinforced gypsum construction board. ASTM Test Standard C79 standard specifications for
8 gypsum construction board require that specimens shall surpass an average surface water
9 absorption of not more than 1.6g after 2 hours of elapsed time (Section 5.1.7). While gypsum
10 construction board is required to meet the above ASTM standards, moisture resistance and
11 adverse weather conditions have been long-term problems with gypsum board. The improved
12 gypsum board of the instant invention comprises an improved moisture resistant cover and core
13 material that far surpasses ASTM C79-5.1.7. Thus, the present invention improves the structural
14 strength, moisture resistance, and weight factors in the design of a new improved gypsum board
15 to be utilized as a construction material.

16 Gypsum board manufacturing is a complex process from the collection of the gypsum
17 rock to the production of the completed construction board. However, the improved gypsum
18 construction board product of the instant invention, as described more fully in the examples
19 below, offers yet another benefit over previously known construction board products, in that it
20 provides increased production capacity from a given gypsum supply over traditional gypsum
21 products and methods of manufacture. More particularly, the technology of the present
22 invention allows for decreased set times from the pin mixer to the knife in laboratory testing,
23 which in turn increases boardline manufacturing speeds far beyond what is currently being

1 realized. As manufacturing speeds increase, so does production, enabling greater amounts of
2 construction board to be produced to meet the current demand. This complex formulation of
3 binders can be seen to be utilized in a wide variety of other building materials as well.

4 Yet another improvement of the gypsum construction board product of the present
5 invention comprises the environmental improvements realized through the use of the specific
6 binders recited herein. Environmental factors must be evaluated when selecting the preferred
7 adhesive, such as noxious fumes emitted in burning test samples and kiln stack emissions while
8 heating and drying the board during the manufacturing process. Plant operational environmental
9 concerns and plant kiln stack emissions are critical factors for manufacturers to consider in
10 evaluating the use of synthetic adhesives. Petrochemical-based acrylics exhibited higher stack
11 emissions, noxious fumes in burn tests, and presented more environmental operational concerns
12 over similar percentages of vinyl acetate emulsions and water based non-V.O.C acrylics and
13 polyurethanes. Further, the specific adhesives used in the construction board product of the
14 instant invention provide a reduced half-life over commonly used adhesives. The adhesives used
15 in the construction board product of the instant invention decompose very quickly and easily.
16 Thus, the improved construction board of the present invention provides a lightweight,
17 strengthened, fire retardant, whitish-covered Perlite and gypsum construction board with
18 environmental improvements that is competitively priced to traditional gypsum construction
19 board products.

21 DETAILED DESCRIPTION OF THE INVENTION

22 The preferred composition of the improved gypsum construction board product of the
23 present invention comprises a binder especially selected for the property of permanent tackiness

1 in the dry state, preferably a self-crosslinking permanently tacky polymer, and more particularly
2 includes a starch, boric acid, vinyl acetate emulsion or water based non-V.O.C. acrylic or
3 polyurethane emulsion, perlite, and gypsum. In an alternate embodiment, such composition
4 includes starch, boric acid, a blend of polyvinyl acetate or polyvinyl alcohol with an organic
5 polymer, and more particularly an amino resin selected from the group consisting of aniline
6 formaldehyde resin, melamine formaldehyde resin, urea-formaldehyde resin, and urea-melamine
7 formaldehyde resin, in combination with perlite and gypsum. It has been found that these
8 combinations (in the proportions set forth below) offer the best results for weight, strength,
9 setting and bond of the construction board core. After applying and analyzing a wide variety of
10 adhesives by themselves and in combination with one another, it was determined that a binder
11 having the composition set forth herein would allow the construction board to perform as closely
12 to what is currently used while adding strength and reducing weight.

13 The strengthened core of the improved gypsum construction board of the instant
14 invention contains expanded Perlite in the range of 0.5 to 60% volume by weight. The expanded
15 Perlite ranges in sizes from 100 to 2000 microns, and preferably from 200 to 1000 microns. The
16 following is a typical sieve analysis of the preferred grade: 11.5% retained on 16, 39.1% retained
17 on 30, 24.3% retained on 50, 12.9% retained on 100 and 2.8% retained on 200. The preferred
18 grade loose density ± 1 pound is 4 pounds per cubic foot and has a compacted density of 5.5
19 pounds per cubic foot. Hard Perlite ore having a high compaction resistance is a very dense
20 concentric ore located within the inner perlitic dome, while softer, low compaction resistant ores
21 are located in the frothy pumicious outer surface of the perlitic dome and are very friable. The
22 expanded Perlite utilized in the construction board of the instant invention is preferably derived
23 from classical concentric granular ores from the middle of the perlitic dome, which ores are able

1 to achieve densities in the 4 to 8 pound range, in order to minimize the expanded density and
2 weight of the Perlite used in the composition of the instant invention while maximizing its
3 strength. While Perlite has been used in the past in small quantities as a filler or additive in
4 gypsum board compositions, the instant invention utilizes expanded Perlite as part of the
5 composite core, adding strength to the core as the binder grabs onto the Perlite.

6 The combination of starch, boric acid and vinyl acetate or water based non-V.O.C.
7 acrylic or polyurethane emulsion, or alternately of starch, boric acid and a blend of polyvinyl
8 acetate or polyvinyl alcohol with an organic amino resin, in itself is sufficient to bond the Perlite
9 together in producing the composite core of the instant invention. However, the combination of
10 gypsum and perlite in the formulation of the improved construction board product of the instant
11 invention, in comparison to other cementitious materials, is preferred due to excellent
12 compatibility of the components described herein.

13 It is important to note that the unique adhesive technology that is described below is
14 completely new and unobvious to the manufacture of construction board products. This process
15 adds a synthetic variable into an already well-used natural adhesive formulation of starch and
16 borate. When starch is treated with borate, interchange linkages are formed throughout the
17 borate anion structure resulting in modifications of the physical properties of the polymer
18 system. The overall result is a binder which, during the construction board manufacturing
19 process, undergoes a chemical change which provides for complete crosslinking between the
20 starch, borate, and synthetic adhesive to form a strengthened web for gripping the gypsum and
21 perlite and forming a rigid core.

22 Starch and borate are often added to the traditional construction board composition in
23 order to protect the delicate gypsum crystals and to ensure proper crystal growth of the gypsum

1 constituent of the construction board core as the board is heat treated in a drying kiln at extreme
2 temperatures. However, as mentioned above, starch and borate also combine to form a natural
3 adhesive. Traditional gypsum compositions do not utilize an additional binder to give the board
4 strength, but rather rely on gypsum crystal growth brought about by heat treatment of the board
5 in its final manufacturing stage. Thus, traditional gypsum construction board compositions do
6 not rely on the adhesive nature of the combination of starch and borate. Borate is not utilized as a
7 standard constituent in all construction board core formulations in the industry, but is preferred
8 by some and is always added to fire rated board formulations as a fire retardant.

9 The construction board composition of the present invention, however, does require an
10 additional binder. It has been found that adding another polymer, namely a vinyl acetate
11 emulsion or water based non-V.O.C. acrylic or polyurethane emulsion, or alternately a blend of
12 polyvinyl acetate or polyvinyl alcohol with an organic amino resin, to the starch polymer and
13 boric acid enables a cross-linking to occur between those constituents. By crosslinking the
14 synthetic polymer chain with the starch and borate polymer chain, more extensive chemical
15 changes are brought about. On a molecular scale, the polymer chain branches extend in all
16 directions, attaching to the gypsum and perlite and increasing the overall strength of the board.

17 Cross-linking of the binder utilized in the present invention with the starch polymer chain
18 is brought about through boron or the use of boric acid. It was originally believed that the
19 commonly used compound boric acid was a sufficient source of boron for the process of the
20 present invention to cross-link the hydroxyl groups of the starch with the vinyl acetate emulsion
21 branch polymer chains. However, large scale test runs of the construction board of the instant
22 invention revealed an occasional high water demand when standard technical grade ortho boric
23 acids were used, especially when introduced into the system in solution as is not uncommon in

1 board production. Laboratory testing revealed that the pH of the boric acid (6.1 in 0.1% solution)
2 and its low molecular weight were causing some fluidity decrease or viscosity increase in slurry
3 formation. In these circumstances, the solution is to replace the boric acid with sodium
4 tetraborate pentahydrate (5 mol) or sodium tetraborate decahydrate (10 mol), the two compounds
5 actually being less costly than the ortho boric acid. The amount of borax or boric acid should be
6 limited in the range of not higher than 0.35% of the total wet weight of the final slurry or more
7 specifically not more than 0.1% of the total amount of synthetic binder utilized (by weight), as it
8 has been found that higher concentrations can cause gelling of the polyvinyl acetate emulsion
9 and affect strength.

10 The particular type of board starch utilized is yet another important consideration.
11 Starches, or more specifically unmodified cereal flours and modified corn starches, are
12 commonly utilized in gypsum board production to provide a better interface between the paper
13 and the core and to protect the gypsum crystal during drying of the board, as well as to allow for
14 increased paper bond. A large number of starch grades can be utilized from lower grade cereal
15 flour to high grade very thin boiling starches which are acid treated. Gelling and flow properties
16 as well as compatibility are better in the higher-grade starches produced from dent corn. The
17 quantity utilized in standard construction board production can range anywhere from 5 to 12
18 pounds per thousand square feet (MSF). Typically this range is from .20 to .50 percent of the
19 wet board weight (MSF). Testing conducted in the laboratory showed better resulting strength
20 development using the formulation of the present invention and starch in the range of 0.30 to
21 0.75 percent by weight (MSF) in combination with the synthetic binder. Higher grade acid
22 modified starches worked well in combination and to cross-link with the vinyl acetate emulsion.
23 Further testing revealed other types of starches, including oxidized thin boiling starches, worked

1 well if not better than acid modified starches. In some situations, oxidized starches are highly
2 compatible with vinyl acetate emulsions as are acid treated starches. But in situations where the
3 gypsum stucco has clay impurities, the oxidized starch can grab onto the vinyl acetate emulsion
4 and block flocculation of clay particles with the polyvinyl alcohol, virtually eliminating "clay
5 shock" and viscosity problems experienced in formulations where clay shock occurs. Although
6 slightly higher in cost, oxidized starches are believed to be the least expensive and simplest
7 solution in these clay situations. The gelling and fluid characteristics of starch play a larger role
8 in the formulation of the present invention than in standard construction board formulations.
9 Instead of the majority of the starch migrating to the face to protect the core to paper bond, much
10 of the starch is retained in the core to chemically combine with the synthetic additive to fuse the
11 minerals together. This cross-linking of the starch and synthetic additive is key to the strength
12 development of the core of the lightweight construction board of the present invention. In all
13 tests, the higher grades, meaning flash dried, wet milled modified starches gave the best results
14 in nail pull and flexural strength ASTM testing procedures over the lower grade, dry milled, belt
15 dried starches requiring less processing than higher grade starches. The use of more intensely
16 processed starches is somewhat a factor to consider in determining the optimum final
17 construction board costs.

18 By introducing vinyl acetate, polyvinyl acetate copolymer, a vinyl acetate-ethylene
19 copolymer, a water based non-V.O.C. acrylic or polyurethane polymer, or a blend or polyvinyl
20 acetate or polyvinyl alcohol with an organic amino resin, into the compositions of the
21 construction board of the instant invention, the resultant complex molecule is much larger,
22 extending its various branches in all directions. It is this desirable change in the polymeric
23 structure of the molecule to a more highly branched chain polymer of higher molecular weight

1 that produces an adhesive with increased viscosity, quicker tack, and better fluid properties.
2 These qualities are crucial to the strength of the most preferred embodiment of the invention.
3 Listed below are two main benefits of this polymer adhesive system. First, increased flexural and
4 compressive strength is realized over current gypsum board ASTM standards. Secondly, the
5 unique polymer adhesive composition of the instant invention enables a construction board
6 composition that is up to as much as fifty percent lighter than current gypsum board.

7 The vinyl acetate emulsion used as the binder in one embodiment of the instant invention
8 produces very favorable test samples and test results. The vinyl acetate emulsion is a milky white
9 liquid, with typical characteristics in the range of a melting point of 32°F to 39°F, a vapor
10 pressure of 16 mm Hg to 22 mm Hg (68°F to 70°F), specific gravity of 1.0 to 2.0, vapor density
11 of from less than 1 to 1, a boiling point of from 212°F to greater than 212°F, and the emulsion is
12 water miscible.

13 In general, Vinyl Acetate Polymers (VAP's) such as the vinyl acetate emulsion used in
14 one embodiment of the composition of the instant invention are hard, brittle, yet tough resins
15 which are found overall to be favorable to the board installation process which requires that the
16 construction board have the ability of being cut and cleanly snapped with a common utility knife
17 after the board has been scored. Additionally, each of the various vendor-supplied VAP's that
18 were tested, when combined in the unique percentages of gypsum and perlite samples tested,
19 were found to be environmentally friendly and not noxious during heat testing. Further, each of
20 the VAP formulations available clearly exhibited the cross linking with starch and mineral
21 (through the use of boric acid), whereby a fusion occurred between the minerals and the adhesive
22 composition. It is thus firmly believed that a chemical fusion of organic and inorganic elements
23 in the composition of the instant invention occurs, rather than a mere adherence by the binder to

1 the mineral. Thus, a fusion occurs which results in a chemically changed binder combination
2 which, when heated, in turn chemically fuses the board formulation.

3 The characteristics of the final vinyl acetate emulsion depend largely on the
4 characteristics of the polyvinyl alcohol used during the manufacture of the emulsion. Wide
5 ranges of polyvinyl alcohols (PVAI's) which can be made are directly dependent upon the
6 characteristics of the intermediate polyvinyl acetate (PVA), especially the PVA's molecular
7 weight and hydrolysis process. PVAI's are generally classified by the percentage of hydrolysis
8 and their degree of polymerization. All polyvinyl alcohols will work in the instant application
9 which are hydrolyzed in preferable ranges from 80 to 100%. Their degree of polymerization
10 based on viscosity at approximately 20°C of 4% aqueous solution, in the range of 5cP (low
11 viscosity) to 60cP (high viscosity) will work in the application. The degree of polymerization of
12 grades which work are in the range of 500 to approximately 2500. The specific PVAI chosen,
13 including the viscosity of the final polyvinyl acetate emulsion, or the derivative of PVAI chosen,
14 shall be field lab or field trial selected. It is primarily dependent on the chemical composition of
15 the gypsum ore, the chemistry of the metered water, and to a significant extent the overall
16 chemical makeup of the constituent additives together. As the temperature increases in the
17 metered water or plant conditions, solubility increases. The fluidity of the wet gypsum slurry
18 finally produced can be directly effected by the proper selection of the PVAI and the final PVA
19 emulsion. Low molecular weight (ca 70-80%) PVAI hydrolyzed grades dissolve rapidly in water
20 at normal room temperatures. It should be noted that solutions of PVAI's in vinyl acetate
21 emulsions mix and disperse more readily in construction board production. They also perform
22 better against "clay shock," as discussed elsewhere in this specification. High molecular weight
23 PVAI's (ca 95-100%) hydrolyzed grades will generally exhibit higher tensile strength. Higher

1 molecular weight PVAI's are dissolved by dispersing in cold water and heating to approximately
2 80-90°C with stirring. Middle range molecular weight (ca 80-95%) grades through hydrolysis
3 are dissolved through slow addition to cold water with stirring, although the temperature can
4 then be raised to 60-80 °C to hasten the process.

5 All VAP's including vinyl acetate homopolymers and copolymers tested were found
6 sufficient to cross-link with starch and boric acid and perform quite satisfactorily in construction
7 board applications. VAP emulsions exhibited preferable mixing ease, dilution and dispersion in
8 the metered process water, and into the final wet gypsum slurry. Homopolymer emulsions were
9 found quite favorable due to their lowest cost, their rapid setting speed, their good ability to
10 adhere to difficult surfaces, and their "dried" strength. Emulsion homopolymers and copolymers,
11 containing polyvinyl alcohol (PVAI) at the right percentages and molecular weight tested (as set
12 forth below), increase the adhesion and cohesion strength, and increase the stabilization (thus the
13 site storage ability) of the final vinyl acetate polymer.

14 Lower molecular weight PVAI's worked better in the presence of sizable clay percentage
15 gypsum ores (i.e., above 1%), to enable initial less thickening of the final wet gypsum with
16 perlite stucco. Higher molecular weight PVAI's increase the absorption of binder molecules
17 onto the particles of the clay minerals or flocculation of clay particles producing in effect "clay
18 shock." The correction for this phenomenon is to utilize lower molecular weight PVAI's that are
19 partially polymerized and hydrolyzed. Thus in essence, they are less "prepared" PVAI's. Partly
20 hydrolyzed grade PVAI's such as GL-02 polyvinyl alcohols of zero to approximately 35 percent
21 to water concentrations should be utilized or added as an anti-shock agent, where there is a fairly
22 sizable presence (i.e., above 1%) of clays in the gypsum, or in the presence of sizable clay
23 percentages (i.e., above 0.1%) in the recycled construction board paper being utilized. The

1 partly hydrolyzed grade PVAI's is provided in 25% solution with water, which solution in turn is
2 present at approximately 5% to 30% by weight of the binder.

3 The inventor herein has recently discovered a phenomenon that occurs when polyvinyl
4 acetate (PVA) emulsion is added to beta hemi-hydrate gypsum in the practice of the instant
5 invention, and a solution to correct this phenomenon, as follows. When PVA is introduced into
6 the standard construction board manufacturing apparatus, slurry thickening occurs in the pin
7 mixer as the constituents are combined, in turn causing an increase in viscosity which creates an
8 increased water demand to maintain or regain a proper fluidity in the slurry. The increased water
9 demand is a problem in that more energy is required to drive off the excess moisture, and
10 strength is also compromised. The following is an example of post addition of lower molecular
11 weight PVAI to the PVA emulsion before introduction into the pin mixer under conventional
12 construction board line manufacturing production in order to reduce or altogether eliminate the
13 clay shock or thickening phenomenon. A 10% to 30% solution of PVAI and water (the specific
14 concentration depending upon the severity of the thickening and being easily determined upon
15 inspection during production) is mixed to batch with the PVA emulsion. The ratio of between
16 10% to 30% PVAI solution is between 5 and 20 parts PVAI to 80 and 95 parts of PVA emulsion,
17 and can be blended together until a homogenous mix is obtained. The above procedure is
18 practiced prior to the emulsion being utilized in the process of this invention, and the two
19 constituents can be recirculated together to combine once the PVAI is placed into solution. Too
20 much PVAI can affect strength and can cause hydration problems in the system, so the proper
21 ratio is essential. It is particularly of note that due to the siliceous nature of some gypsum
22 deposits, the 10% solution of PVAI may not be sufficient at 5% of the PVA to solve the
23 thickening issue, such that higher concentrations of PVAI would be required to solve the

1 problem. Again, the precise concentration may be easily determined upon inspection during
2 production of the construction board of the instant invention. In addition, a small amount of
3 Sorbitol (between 0.1% and 5%) in approximately 70% solution can act as a vehicle for the
4 gypsum to attach to instead of attaching to the polyvinyl alcohol contained within the PVA
5 emulsion itself. This is the purpose of post adding the lower molecular weight PVAI to the PVA
6 emulsion, namely, to counteract the reaction causing the thickening allowing more PVAI to react
7 with the gypsum. It is believed that the chemical reaction that occurs when PVA is added to the
8 stucco can be countered with the post addition of the lower molecular weight PVAI. While it
9 would be most preferable to blend the PVA with the lower molecular weight PVAI at the
10 emulsion manufacturing site so as to be ready to use when received at the construction board
11 manufacturing facilities, the current need of evaluating the thickness of the slurry during board
12 production to establish the appropriate concentration requires that the two constituents be
13 combined at the board manufacturing facility.

14 Thickening of the final gypsum/perlite slurry can also be corrected or further corrected
15 through other methods. One simple solution is to utilize oxidized starch in the presence of
16 PVAI's or PVA's. Further improvements in fluidity will occur when waxy oxidized starch is
17 used. The type of starch used, or preferred, is discussed in other parts of this specification.
18 Higher-grade starches will produce better reactions and strength results, and should be weighed
19 in terms of total cost in determining the final selected and prepared PVAI and PVA copolymer or
20 homopolymer emulsion utilized.

21 It was also found favorable to raise the glass transition temperature (T_g) of the polymer
22 system for better fire testing results of the samples tested. A higher fire rating using VAP's
23 would certainly be preferred in construction board applications. The T_g range from 28°C to

39°C, with higher T_g being preferred in VAP applications, were examined during fire tests, and yet all were found acceptable. In order to obtain higher transition temperatures (T_g), other copolymers may be prepared and/or pre-added to the emulsion in smaller quantities, such as 2-ethyl hexylacrylate, ethyl acrylate, dibutyl fumarate, vinyl stearate, polymethyl methacrylate, or butyl methacrylate. Cost should be considered in percentages used as these will generally increase the overall modified polymer emulsion cost.

It has been discovered by the inventor herein that the selected binder can be caused to foam when mixed vigorously enough with processed water. The foamed binder can aid in aerating the board and decrease or even eliminate the need for soap foaming agents currently used to aerate construction board in manufacturing. This in turn reduces the cost of the board manufacturing process by reducing the need for soap foaming agents. It is believed that soap bubbles and soaps in general do nothing for and actually tend to diminish the strength of the ground gypsum, perlite particles and/or other dry constituents from bonding or cohering to each other and then to the board paper plies. Soaps used today do not aid in sticking or gluing particulates together but separate or repel them from doing the same. Therefore, the binder need be of proper combination and viscosity to form the proper sized bubbles and remain reasonably constant through the kiln drying process to properly aerate the finished board. Polyvinyl acetate emulsions when mixed properly with water, similar to soaps, will foam and can produce a stronger same size bubble due to their surfactant content.

The binder or emulsion can also be slightly altered in viscosity by adding other binders or foaming agents to enhance proper sized bubbles that react similarly, yet firmer, than soap bubbles. Examples of nonionic surfactants which can be useful in this invention are polyethers, e. g., ethylene oxide and propylene oxide condensates which include straight and branched chain

1 alkyl and alkaryl polyethylene glycol and polypropylene glycol ethers and thioethers;
2 alkylphenoxypoly (ethyleneoxy) ethanols having alkyl groups containing from about 7 to about
3 18 carbon atoms and having from about 4 to about 240 ethyleneoxy units, such as
4 heptylphenoxy-poly (ethyleneoxy) ethanols, octyl-and nonylphenoxy-poly (ethyleneoxy)
5 ethanols; the polyoxy-alkylene derivatives of hexitol (including sorbitans, sorbides, manitans and
6 mannides); partial long chain fatty acid esters, such as the polyoxyalkylene derivatives of
7 sorbitan monolaurate, sorbitan monopalmitate, sorbitan monostearate, sorbitan tristearate,
8 sorbitan monooleate and sorbitan trioleate; the condensates of ethylene oxide with a hydrophobic
9 base, said base being those formed by condensing propylene oxide with propylene glycol; sulfur
10 containing condensates, e. g., those prepared by condensing ethylene oxide with higher alkyl
11 mercaptans, such as nonyl, dodecyl, or tetradecyl mercaptan, or with alkylthiophenols wherein
12 the alkyl group contains from about 6 to about 16 carbon atoms; ethylene oxide derivative of
13 long chain carboxylic acids, such as lauric palmitic, oroleic acids or mixtures of acids, such as
14 tall or fatty acids; and ethylene oxide derivatives of long chain alcohols such as octyl, decyl,
15 lauryl, of cetyl alcohols.

16 The preferred nonionic surfactants useful to be added to the latex polymer for the purpose
17 of dispersing the latex polymer throughout the gypsum slurry and creating a stronger bubble than
18 can be achieved with the more commonly used wallboard foaming agents are higher (greater
19 than C8) aliphatic alcohol alkoxylates, aliphatic acid alkoxylates, higher aromatic alcohol
20 alkoxylates, fatty acid amides of alkanolamines, fatty acid amide alkoxylates, propylene glycol
21 alkoxylates, block or random copolymers of ethylene and propylene oxide, higher (greater than
22 C8) alcohol polyethylene polypropylene block or random adducts and mixtures thereof. Of the
23 above classes of nonionic surfactants, the alcohol ethoxylates and alkaryl ethoxylates are

1 particularly preferred. In practice, the amount of nonionic surfactant to be added to the latex
2 polymer is about 1 to about 30 parts per 100 parts of polymer.

3 Additionally, the binder or emulsion can be pre-mixed with the starch in solution to
4 further enhance or control the foaming presence. The most important difference however from
5 just using soap foam water is that the final combined binder solution bubbles will grab onto and
6 adhere to the gypsum, perlite or expanded mineral, and other dry ingredients in the pin mixer and
7 then grab onto the board paper to form more bonded, firm, and therefore stronger composite
8 construction board.

9 Additionally, water based non-V.O.C. acrylic or polyurethane polymer systems can be
10 utilized as the binder in the formulation of the construction board of the present invention either
11 alone or in combination with other polymer systems mentioned herein. The benefit of using a
12 water based non-V.O.C. polymer system in formulating the composite core from an
13 environmental standpoint is a polymer that is completely non-toxic to the workers who work
14 with it as well as having no detrimental effects on the ecosystem surrounding the manufacturing
15 plant where it is being utilized. Being water-based, the system is very compatible with the other
16 constituents that make up the core of the gypsum construction board of the instant invention. The
17 non-V.O.C. polymer system is completely biodegradable and safe to the environment as opposed
18 to petrochemical polymers and worked as well as or better than many of the petrochemical based
19 polymers tested.

20 In addition to using water based non-V.O.C. acrylic or polyurethane polymer systems, a
21 blend of organic and inorganic polymers in an alternate embodiment of the instant invention
22 likewise provides superior adhesion and cohesion properties. More particularly, polyvinyl
23 acetate or polyvinyl alcohol and an organic polymer selected from the group consisting of aniline

1 formaldehyde resin, melamine formaldehyde resin, urea-formaldehyde resin, and urea-melamine
2 formaldehyde resin will crosslink with one another in the presence of formaldehyde and a borate
3 ion. When such organic polymers are added to the construction board composition of the instant
4 invention, reactions occur that form the blended polymer into a three dimensional molecular
5 structure completely crosslinking with the inorganic minerals of the system to form a
6 strengthened composite construction board core. Such core construction has been found to
7 provide a construction board with increased flexibility and strength over prior known
8 construction board compositions, such that the board may readily withstand construction
9 movement and installation stresses, particularly when compared to prior construction board
10 compositions comprising starch as an adhesive with paper fibers or fiberglass fibers added for
11 attempted increased flexibility and strength. Moreover, the use of such a blended polymer
12 composition adds fluidity and reduces cost in the manufacture of the construction board.

13 The above-noted amino resins have characteristics that are favorable to construction
14 board applications, such as being self-extinguishing, resistant to oil, grease, acid, and organic
15 solvents, easy to fabricate, thermosetting, and exhibiting good rigidity and excellent deformation
16 under stress loading. A cellulose filler may be added to such amino resins in combination with
17 the vinyl acetate and polyvinyl alcohol as discussed at length above to further reduce cost and
18 reduce light transmission.

19 In use, the selected amino resins are added in up to 99 parts per 100 parts of the polyvinyl
20 acetate/polyvinyl alcohol in order to increase the initial set strength of the polymer. Preferred
21 aqueous solutions of the above-noted amino resins consist of 55% to 70% solids. The cited
22 amino resins are preferably blended with the polyvinyl acetate in a range from about 40:60 to
23 about 60:40. However, other proportions will also work, with the ultimate blend range of

1 polyvinyl acetate to amino resin depending upon the purity of the gypsum plaster, and what other
2 components are present, such as clay or limestone. The more pure or close to 100% purity the
3 gypsum stucco is, the less amount of polyvinyl acetate will be required to achieve sufficient
4 strength development.

5 A compatible fire retardant, such as boric acid, zinc borate, sulfamates, diammonium
6 phosphate, nitrogen compounds, antimony oxide, silica, titanium oxide, zircon and others can be
7 used and comprise from about .15 percent to about 3 percent by weight of the board. These fire
8 retardants can be added to the formulation by powder or solution during the slurry mixing
9 process, and also by spraying onto the paper covering for the purpose of fire retarding the
10 laminate covering paper of the construction board. The examples of applying fire retardants are
11 listed as follows:

12 Example 1 (Fire retardant, moisture resistant system): this system sprays fire retardant
13 solutions directly onto the board as it leaves the cascade sections and enters the take off area of
14 the manufacturing equipment. This is accomplished by using spray heads overhead together
15 with switch activators to trigger the action as the board passes by on the conveyor. Additives are
16 supplied by storage tanks and pressure type discharge systems. The additives are sprayed
17 directly on the face paper.

18 Example 2 (Fire Retardant): another way to apply a fire retardant quality to the paper is to
19 add it in dry form during the Krafting process of the paper's manufacture. Small particle
20 distribution of fire retardant are added to the pulp slurry prior to extrusion into the paperboard.
21 This allows for the fire retardant to be completely integrated into the paper. This fire retardant
22 could be zinc borate, antimony oxide, nitrogen compounds or sulfamates (sulfur compounds).
23 These are all common fire retardants in paper.

1 Fire Retardant additives to the adhesives, such as the addition of boric acid, reduce the
2 overall flash point of these chemicals and therefore increase the fire rating of the core composite.
3 Under fire rating test samples, the presence of noxious fumes were greatly reduced even to the
4 point of being virtually eliminated as the samples moved away from the epoxies and non-water
5 solvent adhesive mixtures. The combination of vinyl acetates with cementitious materials also
6 provided a good fire retardant combination without the addition of boric acid.

7 Optionally, an improved construction board cover material consists of a manila colored
8 moisture resistant paper face sheet in the range of 40-50 pounds with an altered top ply. In
9 traditional construction board structures incorporating a cover material composed of recycled
10 paper pulp, the length of fibers in the cover material is between 1/2 and 3/4 inches. The instant
11 invention, however, employs a top ply sheet composed of virgin fibers of 1 inch or greater.
12 While papers incorporating fiber lengths of greater than 1 inch have been produced in the past, to
13 the best of the inventor's knowledge, no such virgin pulp has been applied previously to the top
14 ply cover sheet of a construction board sheet. Thus, the inclusion of such extended length fibers
15 into the construction board cover sheet of the instant invention provides the unforeseen and
16 unobvious benefit of providing a much stronger break strength than previously known
17 construction board structures.

18 The unique application of the optional spec paper cover sheets of the construction board
19 of the present invention is completely formed by any well known paper forming process. Using
20 100 percent "virgin stocks" for the top ply of the face paper cover sheet allows for predictable
21 liner strength while also eliminating some of the clays and fillers associated with current
22 completely recycled construction board paper. By integrating a virgin pulp top ply with existing
23 recycled construction board paper plies, increased strength and wet handling characteristics are

1 achieved. First, a paper cover sheet is made generally comprising a multiply sheet
2 manufactured on a cylinder machine. Conventional sizing compounds are added to selected vats
3 such as rosin and alum to internally size some or all plies. The plies are removed and laminated
4 to form an essentially unitary web of paper. After being dried, the paper is coated with a water
5 emulsion of the synthetic size of the class consisting of certain substituted succinic acid
6 anhydrides, certain substituted glutaric acid anhydrides and the reaction product of maleic acid
7 anhydrides with an internal olefin. This process allows for effective absorption into the bond
8 liner of the core side of the paper to provide a mechanical linking of the paper to the composite
9 core.

10 Alternately, a cover sheet may be utilized comprising a combination of non-wood type or
11 organic fibers such as Kenaf with or without recycled waste paper wood pulp fibers. Utilizing a
12 completely or partially tree-free pulp creates a construction board having a more environmentally
13 friendly cover sheet than traditional construction board products. Typically, recycled wood pulp
14 fibers are shorter in length, by up to half, over their virgin pulp counterparts, and the strength that
15 papers manufactured with virgin pulp fibers achieve cannot be duplicated with recycled fibers.
16 However, papers manufactured with virgin wood pulp fibers are much more costly when
17 compared to the cost of papers manufactured with the recycled wood waste pulp variety. By
18 integrating stronger non-wood type organic fibers into the recycled wood waste pulp during the
19 paper manufacturing process, a much thinner but stronger paper cover sheet is realized, allowing
20 the construction board of the instant invention to more easily meet ASTM and Building Code
21 requirements when very lightweight core formulations are being utilized. The weight percentage
22 of fiber of a source other than wood can vary from 1 to 100 percent of the pulp formulation
23 depending upon the desired end result.

As yet another alternative, the paper cover sheets of the construction board of the instant invention may be reinforced using fiberglass mesh material integrated between the inner face liner of the paper cover sheet and the remaining laminates to produce highly abuse-resistant lightweight construction boards. When utilizing formulations to produce construction boards with densities at under 30 pcf (pounds per cubic foot), flexural strength can be reduced significantly in the core. By integrating a fiberglass mesh material beneath the inner surface laminate of the paper facer, flexural or paper grain strength can be retained well above ASTM utilizing slurry formulations to produce abuse-resistant construction boards of the instant invention as low as 25 pcf density. As paper is the majority of the strength of gypsum construction board, this fiberglass mesh material also strengthens sheer panel strength of the invention when utilizing lightweight construction board core formulations of the instant invention. The paper facers utilized in the production of gypsum construction board are normally made on cylinder machines from recycled paper in order to produce a porous paper capable of receiving the gypsum crystals that grow from the wet core slurry prior to drying. The placement or integration of the fibers between the inner liner face of the cover sheet and the remaining laminate layers can be achieved during the paper manufacturing process after the paper is formed into a fibrous web from the pulping process. The introduction of a non-woven fiber mesh into the papermaking process is achieved through placement of the mesh between the fibrous sheets during the laminating process, before dewatering. The same sizing compounds can be utilized and the porous properties of the paper remain the same. The fiberglass material or mesh can be oriented in a variety of crisscross patterns or evenly spaced shapes. Optionally, the mesh can be interlinked similar to a chain link fence within the inner laminate of the facer sheet to further increase its strength. The paper facers will still maintain their ability to absorb

1 the slurry and the properties of the fiberglass will be such that the gypsum crystal can also
2 mechanically link to the fiberglass strands as well. The fiberglass strands can be of various
3 lengths, with the preferred length being 2 inches or greater. The fibers will increase the flexural
4 and racking loads that the wallboard will be able to withstand both during construction and also
5 once the structure is completed. The fiber integration will greatly increase the abuse resistance
6 of the construction board while maintaining lighter weights when compared to abuse resistant
7 boards currently on the market.

8 Even further, the inner liner of the facer sheets can be subjected to an abrasive during the
9 manufacturing process to provide a rough finish, to in turn allow for an improved bonding
10 between the stratum of the gypsum core and the facer sheets. The roughed up liner surface of the
11 facer sheets causes an improved surface for the gypsum slurry crystal growth to adhere with in
12 contrast to the very smooth surfaces found on gypsum wallboard paper facers commonly
13 utilized.

14 If bituminous or waxy water-repellent materials are used, they comprise from about 1.0
15 percent to about 10 percent of the Perlite weight by volume. These materials may be applied to
16 the Perlite from molten states or as emulsions. If silicone emulsions are used, the silicone
17 comprises from about 0.01 to about 2 percent of the Perlite by weight. The silicone emulsions
18 may be applied directly to the Perlite as it exits the expander by means well known in the art.

19 20 Examples

21 The following examples employing the instant invention proved to bring very favorable
22 test results.

EXAMPLE 1

The following is an example of post addition of polyvinyl alcohol to the formulation of the instant invention. A 6 inch by 6 inch by ½ inch sample is prepared using the following formulation:

Materials	Weight in Ounces	Weight by Percentage	Preferred
Gypsum	5.80	42-50%	45.224%
Perlite	0.30	1-3%	2.339%
Board Starch	0.05	0.3-0.6%	0.389%
Accelerator	0.03	0.1-0.3%	0.233%
Boric Acid	0.01	0.01-0.15%	0.077%
Vinyl Acetate	0.30	0.8-4%	2.339%
Polyvinyl Alcohol	0.035	0.1-0.3%	0.272%
Lignosite (dispersant)	0.10	0.07-0.8%	0.779%
Ethoxysulfate (soap)	0.10	0.07-0.8%	0.779%
Water	6.10	42-48%	47.569%

First, the dry constituents, gypsum, perlite, board starch, accelerator, and boric acid are blended until a homogenous mixture is obtained. Next, in a separate vessel, the vinyl acetate and polyvinyl alcohol and dispersant are mixed together with 2/3 of the total water and the remaining 1/3 of the total water is combined with the soap foaming agent and blended to achieve 1/4 inch diameter bubbles of foam. Finally, all of the constituents are combined in a laboratory mixer and blended until 100% of a slurry is obtained. The slurry is then poured into a paper envelope comprising fire resistant and water repellant construction board cover sheets and formed and sealed. After hydration occurs, the sample is placed into a small laboratory kiln to drive off the excess water and dry the board example. The test results for this composition passed ASTM C36 specification.

EXAMPLE 2

1 It has been found that sodium trimetaphosphate may be utilized to increase compressive
2 strength by enhancing cylindrical needle-like crystal growth in the core of the improved
3 strengthened construction board of the instant invention. Sodium trimetaphosphate is a
4 combination of earth metals and is known by the chemical equation $(\text{NaPO}_3)_3$. This compound
5 may be added to the slurry either in solution or in a dry powder state, although in solution is
6 preferred. By adding sodium trimetaphosphate into the system, the favorable long cylindrical
7 crystal growth that adds the most strength to the core of the construction board and also enhances
8 the paper to core bond is greatly increased, and the result is higher compressive strength. The
9 compound is highly water soluble and dilutes very quickly allowing it to disperse very rapidly.
10 The resultant chemical reaction is not entirely understood, although it is believed that the sodium
11 hydroxide and fluoride in the sodium trimetaphosphate reacts with the calcium in the gypsum
12 and increases the crystal growth. The following is an example of the addition of sodium
13 trimetaphosphate to the formulation of the instant invention. A 6 inch by 6 inch by $\frac{1}{2}$ inch
14 sample is prepared using the following formulation:

1	Materials	Weight in Ounces	Weight by Percentage	Preferred
2				
3	Gypsum	6.70	42-50%	47.857%
4	Perlite	0.25	1-3%	1.785%
5	Board Starch	0.05	0.3-0.6%	0.357%
6	Ball Mill Accelerator (bma)	0.02	0.1-0.3%	0.142%
7	Boric Acid	0.005	0.01-0.15%	0.035%
8	Vinyl Acetate	0.15	0.8-4%	1.071%
9	Polyvinyl Alcohol	0.03	0.1-0.3%	0.214%
10	Sodium Trimetaphosphate	0.095	0.01-0.7%	0.678%
11	Ethoxysulfate (soap)	0.10	0.07-0.8%	0.714%
12	Lignosite (dispersant)	0.10	0.07-0.8%	0.714%
13	Water	6.50	42-48%	46.433%
14	First, the dry constituents, gypsum, Perlite, board starch, bma, and boric acid are blended			
15	until a homogenous mixture is obtained. Next, in a separate vessel, the vinyl acetate and			
16	polyvinyl alcohol and dispersant are mixed together with 2/3 of the total water and the remaining			
17	1/3 of the total water is combined with the soap foaming agent and the sodium trimetaphosphate			
18	and blended to achieve 1/4 inch diameter bubbles of foam. Finally, all the constituents are			
19	combined in a laboratory mixer and blended until 100% of a slurry is obtained. The slurry is			
20	then poured into a paper envelope comprising fire resistant and water repellant construction			
21	board cover sheets and formed and sealed. After hydration occurs the sample is placed into a			
22	small laboratory kiln to drive off the excess water and dry the board sample. The test results for			
23	this composition satisfied the criteria of ASTM methods C-36 and C-473.			

EXAMPLE 3

Materials	Weight in pounds per MSF	Weight by %	Preferred
Perlite	60	1-3%	2.564%
Calcined gypsum	1130	42-50%	48.295%
Ball mill accelerator	7.0	0.1-0.3%	.299%
Starch	9.0	0.3-0.6%	.384%
Boric Acid	.25	0.01-0.15%	.015%
Sodium Trimetaphosphate	.50	0.01-0.7%	.021%
Fiberglass fibers	1.5	0.1-0.2%	.064%
Dispersant (lignosulfonate)	2.0	0.07-0.8%	.085%
Soap (foamer)	1.5	0.07-0.8%	.064%
Vinyl Acetate	28.0	0.8-4%	1.196%
Water	1100	42-48%	47.013%

This example discloses a composition reflecting the most preferred embodiment of the improved construction board composition of the instant invention, and continues the study of the addition of various percentages of calcium sulfate into the composite core. It is also a test of an adhesive formulation comprising vinyl acetate polymer emulsion, modified starch, and boric acid. In this test, the first step was to mix about 15% of the preferred Perlite of the invention with the remaining dry constituents. The Perlite 15% (by volume) was combined with modified starch, ball mill accelerator, boric acid, and about 25% (by volume) calcium sulfate. Next, about 5% (by volume) vinyl acetate emulsion was added to soap foam, dispersant and about 50% (by volume) water. The wet and dry ingredients are fed by normal board manufacturing line apparatus into a pin mixer for 3 seconds. The slurry is dispersed onto continuous moving paper cover sheets. The construction board is formed and conveyed to the cutting knife. The board set up fairly hard in under three minutes and was then cut to desired lengths. The board was then inverted and run through a kiln at normal drying temperature parameters for about an hour. Once cooled, the sample was weighed and measured and the results were catalogued. Several days

later this sample was conditioned and then tested to ASTM C473 standards. Test results confirmed nearly double those of the gypsum core control sample in nail pull resistance, edge hardness, and with improved flexural strength.

EXAMPLE 4

Materials	Weight in Ounces	Weight by %	Preferred
Gypsum	10.0	48-55%	51.355%
Ball Mill Accelerator	.05	0.1-0.3%	.244%
Starch	.08	0.3-0.6%	.387%
Boric Acid	.02	0.01-0.15%	.096%
Potassium sulfate	.01	0.05-0.3%	.048%
Lignosulfonate(dispersant)	.01	0.07-0.8%	.048%
Soap (foamer)	.02	0.07-0.8%	.096%
Vinyl Acetate	.35	0.8-4%	1.697%
Water	9.5	42-48%	46.029%

This example discloses the addition of the unique adhesive formulation of the instant invention into traditional gypsum board without an expanded mineral added. Calcium sulfate(gypsum), starch, ball mill accelerator, potassium sulfate, and boric acid were combined in the above amounts. Then, lignosulfonate, Ethoxysulfate, vinyl acetate, and water were combined and mixed into a foamy consistency and combined with the dry ingredients. The mixture was mixed at high speed and then poured into a 6" by 12" form with a construction board paper insert and sealed and formed into a sheet identical to traditional gypsum board. The sample was then removed from the form and the set was timed. After timing the set and allowing the full hydration set to occur, the sample was then heated in a kiln at 180°F to evaporate excess water. Once dry, these boards were left to cure for two days and then tested. These experiments were conducted to evaluate increased strength in traditional construction board compositions with the addition of the synthetic binder. Nail pull resistance, edge hardness, and flexural strength were

increased 150% in all the samples that were made and tested. This decrease in set time and increase in strength of the construction board can allow for increased operating speeds in current board manufacturing facilities. Varying curing temperatures were applied in this example from 75°C to 352°C with favorable test results, including passing nail pull resistance, flexural breaking loads, edge hardness, and humidified bond according to ASTM C36. However, the preferred curing temperatures ranged from 79°C to 275°C.

EXAMPLE 5

<u>Materials</u>	<u>Weight in Ounces</u>	<u>Weight by %</u>	<u>Preferred</u>
Perlite	.40	1-3%	2.366%
Gypsum	8.0	42-50%	47.281%
Ball mill accelerator	.04	0.1-0.3%	.238%
Starch	.07	0.3-0.6%	.413%
Boric acid	.015	0.01-0.15%	.088%
Potassium sulfate	.015	0.05-0.3%	.088%
Dispersant	.02	0.07-0.8%	.118%
Soap (foamer)	.01	0.07-0.8%	.059%
Vinyl Acetate	.35	0.8-4%	2.068%
Water	8.0	42-48%	47.281%

In this example, first the dry ingredients were combined together and blended until a homogeneous mix was achieved, these dry ingredients being plaster grade expanded perlite with a loose density of 6 to 8 pounds per cubic foot, calcined gypsum stucco, starch, ball mill land plaster accelerator, pot ash and boric acid. Secondly, the dry lignosite dispersant was combined with the water and mixed until blended. Thirdly, the soap water and vinyl acetate were combined together and blended with an electric mixer to generate foam or bubbles. The soap water and vinyl acetate foam mix was then added to the lignosite and water and then all the wet ingredients were combined with the dry blended ingredients and mixed by hand for about 15 seconds to achieve 100% of a slurry. The ambient temperature was 82°F and the surrounding

1 humidity was 29%. This slurry was then poured into a fire resistant and water repellant
2 construction board paper insert or envelope to make a 1/2 inch thick board sample measuring 6
3 inches by 6 inches. The back sheet of the insert was then sealed to the face sheet folds using a
4 starch based drywall edge paste, formed, and then removed from the form, and the initial or snap
5 set was timed and recorded. In a typical drywall manufacturing process there are two different
6 sets, first being the initial or snap set, whereas the continuous board hardens or stiffens
7 sufficiently to be cut into desired lengths downstream at the rotary knife. The secondary or
8 hydration set relates to the complete hydration of the gypsum crystals, meaning the amount of
9 time sufficient to rehydrate the calcined gypsum, replacing the two molecules of H₂O removed
10 during the calcining process of land plaster. This secondary hydration set can be from as low as
11 4.6 minutes to as high as 7 minutes depending on the grind and purity of the land plaster being
12 utilized. At 2 1/2 minutes the sample of the above example was cut cleanly and inspected. The
13 inspection revealed that the slurry had sufficiently set and it is believed that the chemical
14 reaction of the synthetic binder (vinyl acetate) and the calcined gypsum allows the gypsum
15 crystal to rehydrate more rapidly than calcined gypsum rehydrated without the synthetic additive
16 of the present invention. The above process has been duplicated repeatedly in the lab with slight
17 variations in formula achieving the same results. A range of volumes of the preferred synthetic
18 binder (vinyl acetate) were tested with gypsum and consistently set times were reduced over
19 those of the gypsum control samples with no synthetic additives, and consistently stronger
20 samples were obtained over those of the gypsum control samples with no synthetic additives.
21 All procedures including the drying of the samples were consistent with typical drywall
22 manufacturing processes. The excess water in the samples was driven off by placing samples in

a laboratory kiln with access to moving heated air at a temperature of between 150°C and 200°C for a period of 50 minutes to 1 hour.

EXAMPLE 6

Materials	Weight in Ounces	Weight by %	Preferred
Perlite	.30	1-3%	1.816
Gypsum	8.0	42-50%	48.434
Starch	.075	0.3-0.6%	.454
Ball mill accelerator	.037	0.1-0.3%	.224
Boric acid	.015	0.01-0.15%	.090
Dispersant	.020	0.07-0.8%	.121
Soap (foamer)	.020	0.07-0.8%	.121
Non-V.O.C. acrylic polymer	.35	0.8-4%	2.119
Water	7.7	42-48%	46.618

This example discloses the other preferred unique adhesive formulation of the instant invention into traditional gypsum board. Calcium sulfate(gypsum), starch, ball mill accelerator, and boric acid were combined in the above amounts. Then, lignosulfonate, Ethoxysulfate, non-V.O.C. acrylic emulsion, and water were combined and mixed thoroughly and was then combined with the dry ingredients. The mixture was mixed at high speed and then poured into a 6" by 12" form with a construction board paper insert and sealed and formed into a sheet identical to traditional gypsum board. The sample was then removed from the form and the set was timed. After timing the set and allowing the full hydration set to occur, the sample was then heated in a kiln at 180°F to evaporate excess water. Once dry, these boards were left to cure for two days and then tested. These experiments were conducted to evaluate increased strength in traditional construction board compositions with the addition of the synthetic binder. The resulting board samples of this particular example surpassed all ASTM C36 specifications. The test results for this composition satisfied the criteria of ASTM methods C-36 and C-473.

EXAMPLE 7

Materials	Weight in Ounces	Weight by %	Preferred
Gypsum	990.0	42-50%	48.072%
Expanded Perlite	50.0	1-3%	2.427%
Starch	10.0	0.3-0.6%	0.485%
Ball mill accelerator	4.0	0.1-0.3%	0.194%
Potassium sulfate	2.75	0.134%	0.05-0.3%
Boric acid	0.25	0.01-0.15%	0.013%
Foaming Agent	1.50	0.07-0.8%	0.073%
Sodium Trimetaphosphate	0.50	0.01-0.7%	0.024%
Ethoxilated Alcohol	0.40	0.01-0.7%	0.019%
Vinyl Acetate Emulsion	28.0	0.8-4%	1.359%
Diloflo (Naphthalene Sulfonate)	2.0	0.07-0.8%	0.099%
Water	970.0	42-49%	47.101%

This example discloses the addition of a straight chain linear ethoxilated alcohol, added to the synthetic binder in a blend prior to its introduction into the system of this invention. By adding the nonionic surfactant to the binder, the polymer has greater dispersion capabilities in the slurry and forms strong or strengthened air entrainment into the matrix. The wetting action of the nonionic surfactant when blended with the polymer also decreases the amount of water needed to achieve a workable slurry. This example exemplifies the most preferred formulation of this invention. The system as a whole will achieve construction board weights up to 40 percent lighter and meets all ASTM standards for C36 gypsum wallboard specifications. This formulation is for use in production runs of the invention and is measured in units per thousand square feet typical to industry practice. The dry ingredients are fed into a mixing conveyor screw from their respective feeders and blended while being conveyed to the pin mixer. The wet ingredients, with the exception of the foam, are blended and fed into the water system upstream of the pin mixer to achieve proper dispersion. The formed construction board is then conveyed on a belt to the knife during which time it has set to a hardness sufficient to be cut at the knife.

After being cut into the desired lengths it is inverted and run through a multi deck board drying kiln. The resulting dry construction board is stacked and housed for shipment to consumers. All of the construction board of this example met or exceeded nail pull resistance, flexural breaking loads, core and edge hardness, and deflection as well as humidified bond requirements per ASTM C36.

The following three examples set forth the use of amino resins as described above, and result in a construction board composition which exhibits increased nail pull, initial set, and fluidity in the presence of clay. Likewise, lesser amounts of the overall polymer are required due to the initial strength development of the core using the formulations set forth below.

EXAMPLE 8

<u>Materials</u>	<u>Weight in Pounds/MSF</u>	<u>Weight by %</u>	<u>Preferred</u>
Gypsum	1042 pounds/ MSF	46-50%	49.431%
Perlite	35 pounds/MSF	1-2%	1.660%
Starch	8 pounds/MSF	.2-.5%	.380%
Accelerator	3 pounds/MSF	.1-.3%	.142%
Fiberglass	2 pounds/MSF	.05-.1%	.095%
Boric Acid	1 pound/MSF	.04-.1%	.047%
Vinyl Acetate	10 pounds/MSF	.4-1%	.474%
Melamine resin	20 pounds/MSF	.5-1.5%	.949%
Foam agent	2 pounds/MSF	.05-.1%	.095%
Naphthalene Sulfonate (Wetting Agent)	5 pounds/MSF	.1-.3%	.237%
Water	980 pounds/MSF	44-47%	46.490%

EXAMPLE 9:

Materials	Weight in Pounds/MSF	Weight by %	Preferred
Gypsum	972 pounds MSF	46-50%	49.041%
Perlite	55 pounds MSF	1-3%	2.775%
Starch	9 pounds MSF	.2-.5%	.454%
Accelerator	7 pounds MSF	.2-.5%	.252%
Pulp fiber	3 pounds MSF	.05-.2%	.151%
Boric Acid	4 pounds MSF	.1-.3%	.202%
Aniline-Formaldehyde-			
Resin	19 pounds MSF	.5-1.5%	.958%
Vinyl Acetate-			
Emulsion	6 pounds MSF	.3-.6%	.303%
Foam Agent	4 pounds MSF	.1-.3%	.202%
Lignin	3 pounds MSF	.05-.2%	.151%
White Dextrin	2 pounds MSF	.07-1.2%	.101%
Water	900 pounds MSF	44-48%	45.409%

EXAMPLE 10:

Materials	Weight in Pounds/MSF	Weight by %	Preferred
Gypsum	1050 pounds MSF	46-50%	49.065%
Perlite	35 pounds MSF	1-2%	1.635%
Starch	8 pounds MSF	.2-.5%	.373%
Accelerator	5 pounds MSF	.1-.3%	.233%
Fiberglass	2 pounds MSF	.05-.1%	.093%
Boric Acid	1 pound MSF	.05-.1%	.046%
Vinyl Acetate	15 pounds MSF	.5-1.5%	.704%
Urea Resin	15 pounds MSF	.5-1.5%	.704%
Foam agent	2 pounds MSF	.05-.1%	.093%
Naphthalene			
(Wetting Agent)	5 pounds MSF	.1-.3%	.233%
Dextrose	2 pounds MSF	.05-.1%	.093%
Water	1000 pounds MSF	44-47%	46.728%